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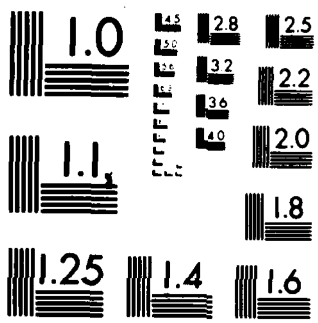


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MICROSCOPIC EXAMINATIONS OF SURFACES EXPOSED
BY CUTTING ICE-RICH FROZEN SANDS WITH A
WIRE SAW

BY

R.G. REIN, JR.

AUGUST 1983

U.S. ARMY RESEARCH OFFICE
CONTRACTS: DAAG 29-79-C-0198

UNIVERSITY OF WASHINGTON
SEATTLE, WA 98195





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A wire saw was used to cut sections of ice-rich frozen sands. Low-power (10X to 40X) microscopic examination of surfaces created by cutting indicated that the saw cut through sand particles and did not dislodge particles from the ice matrix or cause damage to the ice matrix. Optimum cutting parameters for the saw are given. These parameters are consistent with parameters determined in a previous study which used a wire saw to cut frozen silts and loams.

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20: Abstract (continued)

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Ice-particle interfaces, large cracks, and air bubbles were observable with low power microscopy. However, focusing problems, and apparent debris from cutting, limited microphotography of these features and precluded examinations at higher magnifications.

ABSTRACT

A wire saw was used to cut sections of ice-rich frozen sands. Low-power (10X to 40X) microscopic examination of surfaces created by cutting indicated that the saw cut through sand particles and did not dislodge particles from the ice matrix or cause damage to the ice matrix. Optimum cutting parameters for the saw are given. These parameters are consistent with parameters determined in a previous study which used a wire saw to cut frozen silts and loams.

A fibre-optics illumination system provided adequate illumination for microscopic examinations. With fibre-optics illumination systems frozen samples can be observed for long times without melting the samples.

Ice-particle interfaces, large cracks, and air bubbles were observable with low power microscopy. However, focusing problems, and apparent debris from cutting, limited microphotography of these features and precluded examinations at higher magnifications.

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## INTRODUCTION

There would be much more confidence in interpretation of the observed mechanical behavior of frozen soils, and much more confidence in engineering designs involving frozen soils, if the physical processes occurring during deformation were known, and if conditions under which different processes dominate deformation were known. Presently there are no experimental observations that provide this information. Observations of the microstructure of polycrystalline ice (1, 3) suggest that possible processes include: slip in ice grains, grain-boundary migration and distortion, recrystallization, crystal reorientation, and the formation and growth of intracrystalline cracks. However, the conditions under which these different processes dominate deformation still need to be determined, and conditions for the occurrence of these processes in frozen soils needs to be determined.

It is expected that observation of the microstructure of frozen soils after differing amounts of deformation will indicate which processes occur in frozen soils, and the conditions under which different processes dominate. Observation of the microstructure will require a method of cutting sections from frozen soils (sectioning) without dislodging the hard soil particles from the soft ice matrix. This report describes use of a wire saw to section samples of ice-rich sand for microscopic examination, and eventual observation of processes occurring during deformation. It is expected that the results will also apply to sectioning any material consisting of hard particles in a soft matrix.

## EXPERIMENTAL PROCEDURES

This section outlines the sample-making technique used to make ice-rich, remolded sand samples for this study, outlines use of a wire saw to cut samples, indicates problems associated with using the wire saw, describes equipment used for microscopic examination, and indicates problems encountered in microscopic examination.

Soil Samples. Soil samples for the tests were right circular cylinders. Samples were made by compacting mixtures of sand and snow in thick plastic molds, pulling a vacuum on the mixture for 24 hours, then saturating the mixture with partially deaired, 0°-C water. This procedure was intended to minimize the amount of air in the samples. Close-fitting aluminum end plugs with O-ring seals sealed the molds and assured that samples had parallel ends. A small hole in one end plug provided access to the vacuum used to deair sand-snow mixtures. Samples were frozen in a cold room maintained at a nominal -10°C. They were removed from the mold by removing the end plugs and cracking the plastic mold. Molds were cracked by twisting a screwdriver in a groove which had been milled in the mold.

To facilitate observation of the condition of the ice in soils, most samples were ice-rich sand with an ice/sand volume ratio of 4/1 and large sand particles. The large particles also provided a severe test of the cutting technique. Samples were made with a commercial #1 fine sand from which particles smaller than #20 mesh had been removed, a #1 sand-blasting sand (which provided larger particles for more severe tests of cutting techniques), and Manchester fine sand ($D_{10}$ =0.1 mm, $D_{60}$ = 0.2mm) to test cutting and observation procedures for samples with smaller particles.

Sample Cutting All cutting was done in a walk-in cold room maintained at a nominal -10°C. A Lastec Model 2006A wire saw was used for cutting. Procedures for using a wire saw to cut frozen soils were outlined previously in an investigation of ice lenses in frozen soils (2), and many of the procedures outlined in that report were used in this study. However, some unique problems were encountered in using the saw to cut presumably harder particles encountered in this study and in obtaining acceptable surfaces for the more detailed observations required in this study. These problems are discussed in this section, and general procedures for using the saw are outlined.

Both regular diamond wires (copper plating holds diamond abrasives on a high-strength wire core) and overplated wire (an additional layer of plating reduces the rate at which abrasive is dislodged from the wire) were used for cutting. 0.076-,0.200-, and 0.381-mm (0.003-, 0.008-, and 0.015-inch) diameter regular wires and 0.200-mm (0.088-inch) diameter overplated wires were used. Acceptable cuts (cuts which gave no evidence of cutting damage in the ice matrix and no evidence of sand particles being dislodged from the ice matrix) were obtained with 0.076- and 0.200-mm (0.003- and 0.008-inch) diameter wires, but there was considerable evidence of sand particles being dislodged from the ice matrix when cutting with 0.381-mm (0.015-inch) diameter wires.

Wire life was much shorter than expected and was limited by the abrasive particles being dislodged from the wire. Only one cut across the diameter of a 25.4-mm (1-inch) diameter sample could be made with regular wire. Even after adjusting cutting parameters to maximize wire life, only three to four cuts could be made with a 30-m (100-ft) length of overplated wire. From 3 to 6 hours were required to cut across a 25.4-mm (1-inch) diameter sample. Best results were obtained with the following conditions:

Wire - 0.200-mm (0.008-inch) diameter, overplated (the smallest diameter overplated wire available).

Wire tension - 3500 gram (the maximum suggested by the manufacturer).

Cutting force - 40 to 50 gram (the minimum force which maintained cutting force on the wire).

Wire speed - 15 to 30 cm/sec (the minimum controllable speed).

These conditions are consistent with the manufacturer's recommendations and with recommendations from a previous study (2). However, contrary to the previous study: wire life was considerably less; surface contamination by cutting debris (discussed in the Results section) was considerably more prevalent; and lubrication of the wire was not effective in eliminating surface contamination.

Microscopic Examination An Olympus Model X-TRA trinocular stereomicroscope with a Model PM-10-A photomicrograph camera system (magnifications from 6.3X to 40X for normal observation and 3X to 20X for photography) was used for examining and photographing surfaces produced by cutting. Most observations were with reflected light, but some thin sections were observed and photographed with transmitted polarized light. Focusing at the sample surface was difficult when using reflected light because light was readily transmitted through the ice between the sand particles, thus causing a tendency to focus on prominent objects below the surface. This problem caused much more time to be spent than expected for observations and required photographs at several focuses when photographing a single area. This problem might be alleviated by observing surfaces of thinner sections (with a narrower range of depths to focus at), but the long time required to cut samples and the short wire life preclude common use of thinner sections.

Because of the focusing problem, cracks were difficult to view, even when using oblique lighting. An attempt to enhance crack visibility by using a solution of Rhodamine B in dichloroethylene was unsuccessful because the solution did not penetrate into narrow cracks, although the solution did penetrate into wide cracks.

To avoid heating samples with the heat produced by usual microscope illumination, a fibre-optics illumination system was used. The system consisted of a Volpi Model 150H light source and a 1250-mm long light guide connected to two focusing illuminators on 240-mm long flexible goosenecks. Important features of this system included: constant temperature illumination with an aperature diaphragm for intensity regulation (to provide a constant color temperature for photography), an infrared heat absorbing filter, and the focusing illuminators on flexible goosenecks (to allow flexibility in orienting illumination of samples). This system performed extremely well and provided adequate illumination while allowing long periods of observation without harm to the samples.

## RESULTS

Figures 1 and 2 are representative photomicrographs of surfaces exposed by cutting ice-rich frozen sands.

Figure 1 shows a surface exposed by cutting a sample of #1 sandblasting sand. The photograph was taken 1/2 hour after the sample was cut. The figure shows that a large sand particle was cut cleanly, and that the ice matrix was not disturbed by the cut. Oriented bands on the ice matrix may be debris from cutting.

Figure 2 shows a surface exposed near the middle of a sample of #1 fine sand that had been deformed 10% in uniaxial compression. The photograph was taken 3 hours after the sample was cut. Two voids (probably air bubbles) are evident in the lower right of the picture, but no cracks, or other evidence of damage are evident. Deformation was

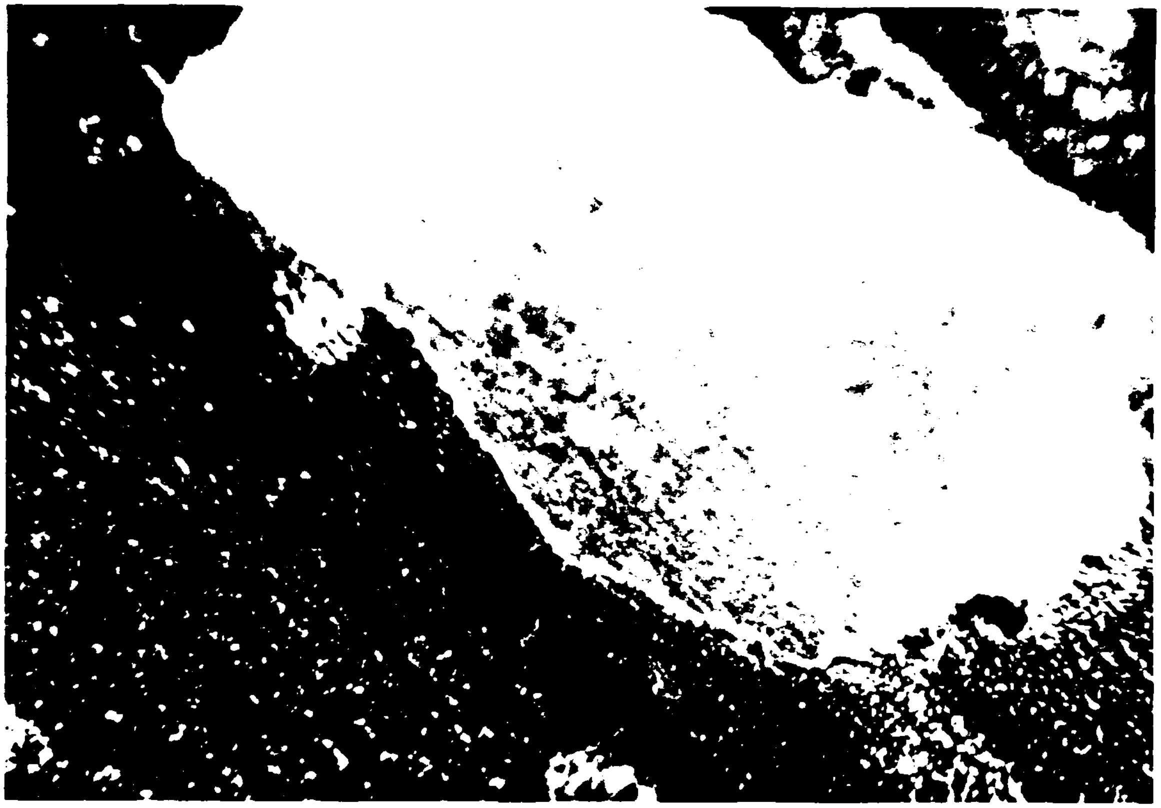

Figure 1. Surface exposed by using a wire saw to cut an ice-rich coarse sand. Photograph taken 1/2 hour after surface exposed. (57 X as shown)

Figure 2. Surface exposed by using a wire saw to cut an ice-rich fine sand. Photograph taken 3 hours after surface exposed. (40 X as shown)

not homogeneous in this sample, and extensive cracking was visually observed near both ends of the sample. Photographs were not taken in these regions because, at the time, it was desired to determine if small, isolated cracks could be observed.

Examination of another sample, which had been deformed 7% in uniaxial compression, and had a more homogeneous distribution of deformation, showed that cracks could be observed with low-power microscopy. Cracks in this ice-rich sample were located near the center of ice grains, and were not initiated at particle-ice interfaces. Suitable photographs of the cracks were not obtained because of difficulty in focusing on the cracks.

Cut particles shown in Figure 2 confirm that the wire saw cuts through soil particles without damaging the ice matrix. The oriented bright bands on the ice may be associated with debris from cutting.

Figures 1 and 2 clearly show that a wire saw can cut through sand particles in frozen sand without damaging the ice matrix. Similar results were obtained when cutting Manchester fine sand, but suitable photographs were not obtained because of focusing problems at the greater magnifications required to observe the smaller particles in these samples. These observations clearly show that a wire saw is suitable for obtaining sections of frozen soil for microscopic examination.

Figure 3 shows a surface of an ice sample 2 hours after the sample was cut. The sample had been deformed 60% (based on the original length) in uniaxial compression, and cracks associated with the deformation are easily seen. The oriented bands observed with cuts in frozen sand to not appear in Figure 3, thus supporting the hypothesis that the bands are debris from cutting.

Figure 4 shows an 0.5-mm thick section from a sample of #1 fine sand. The section is observed with transmitted polarized light. Large, angular dark regions are soil grains. The aligned fuzziness at the edges of soil grains is suggestive of debris from cutting and further supports the hypothesis that the oriented bands observed frequently, and shown in Figuers 1 and 2, are debris from cutting. The many, small, rounded spots in the photograph are probably air

Figure 3. Surface exposed by using a wire saw to cut ice.
Photograph taken 2 hours after surface exposed.
(40 X as shown)

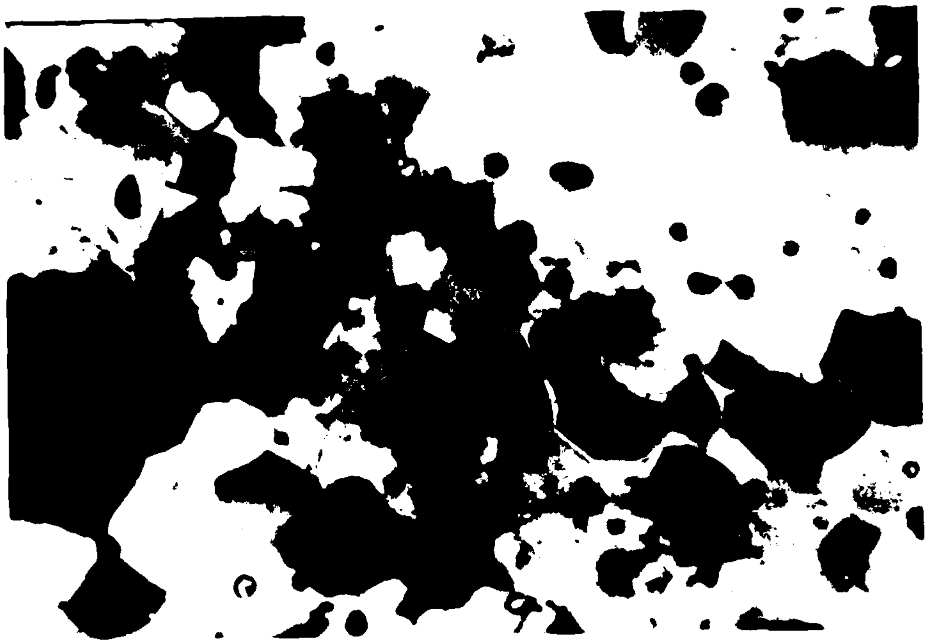

Figure 4. Transmission photomicrograph of 0.5-mm thick section of ice-rich fine sand taken with polarized light. (9.3 X as shown)

bubbles, and indicate that this sample was not as air-free as expected.

CONCLUSIONS

The following conclusions result from this preliminary study of using a wire saw to section samples of frozen sand.

1. A commercially-available, automatic wire saw can cut through sand particles in frozen sands without dislodging sand particles from the ice matrix, or damaging the matrix.

2. Cutting frozen sands with a wire saw takes much time (from 3 to 6 hours to cut across a 25.4mm (1-inch) diameter sample), and wires wear out fast (with optimum cutting conditions, only 3 to 4 cuts across 25.4-mm (1-inch) diameters could be obtained with 30-m (100-foot) lengths of overplated wire).

3. A fibre-optics illumination system can provide adequate illumination for microscopic examination of frozen soils, and also allows long periods of observation without melting the frozen soils.

4. Cracks and air bubbles in frozen sand are observable with low-power microscopy (10X to 40X). However, focusing is a problem in obtaining suitable microphotographs of such features.

5. String-like features often observed parallel to the direction of wire motion are probably debris from cutting.

6. Solutions of Rhodamine B in dichloroethane and in ethyl acetate were not successful in enhancing the visibility of cracks in frozen sands because the solutions would not penetrate into narrow cracks.

RECOMMENDATIONS

1. A wire saw successfully cut many samples of ice-rich sands without dislodging sand particles from the ice matrix, or damaging the matrix. Therefore it is recommended that use of a wire saw be considered whenever it is necessary to cut materials consisting of hard particles in a soft matrix without damaging the matrix.

2. A fibre-optics illumination system provided adequate illumination for microscopic examination of frozen soils and did not melt the ice matrix. Therefore it is recommended that fibre-optics illumination be used for future microscopic examinations of frozen soils.

3. Debris from cutting soil particles apparently interferred with thorough examination of surfaces exposed by cutting with the wire saw. Lubrication of the cutting wires did not solve the problem, but fine polishing of the surface (such as is done in preparing surfaces for metallographic observation) might solve the problem without damaging the surface. Therefore it is recommended that future studies of the microstructure of frozen soil investigate obtaining more satisfactory surfaces for observation by polishing surfaces exposed by cutting with a wire saw.

## BIBLIOGRAPHY

1. Gold, L.W., "Deformation Mechanisms in Ice," in Ice and Snow, W.D. Kingery, ed., M.I.T. Press, Cambridge, Mass., p 8 (1963).

2. Osterkamp, T.E., "Structure and Properties of Ice Lenses in Frozen Ground", Geophysical Institute Report UAG R-233, Sea Grant Report 75-1, The Geophysical Institute, The University of Alaska, Fairbanks, AK. (1975).

3. Voytkovskiy, D.F. and Golubev, V.N., "Mechanical Properties of Ice as a Function of the Conditions of its Formation", in *U.S.S.R. Contribution, Permafrost Second* International Conference, National Academy of Sciences, Washington, D.C., p 217 (1978).

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|---|---|
| Robert G. Rein, Jr. | Principal Investigator |
| Mehmet A. Sherif | Co-Principal Investigator |

## PUBLICATIONS FROM THIS PROJECT

*No publications resulted from this project.*